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COMPUTER-BASED MODELS FOR POLICY MAKING: USES AND IMPACTS IN THE U.S. FEDERAL GOVERNMENT

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This paper examines factors influencing implementation and use of computer models that have been successfully institutionalized as part of federal policy-making. It is based upon detailed case studies of two kinds of models that have been widely assimilated and used in federal agencies—microanalytic simulation models and macroeconomic models. It concludes that the most important influences on successful modeling are the means to do modeling (supply factors) and the desire of bureaucrats and politicians to use model-generated information (demand factors). Of these, demand factors are most important. The availability and promotion of computer models alone is insufficient to generate use, whereas their political saliency is critical. Thus, where the means to do modeling are weak, but the desire to use models is strong, government agencies invest heavily in the creation of new modeling efforts.

1. Models in the Policy Process

Between 1950 and 1970, most applications of operations research models were to operational decision problems that had well-understood objectives and conditions, and that were subject to formal expression and rigorous analysis. Beginning in the late 1960s, there arose a serious effort to apply OR techniques to the problems of public policy analysis (Strauch 1974). Policy analysis problems differ from operational problems in that unambiguous, rigorous representations of the problems are very difficult to construct. The fundamental objectives in policy problems are themselves unclear in many instances (Quade 1982). The gap between the need for formality and rigor in mathematical modeling, and the fuzziness of problems in real-world policy situations, has stimulated considerable skepticism about the applicability of models to policy problems (Churchman 1971, Hoos 1972, Brewer 1973, Brewer and Shubik 1979, Fromm, Hamilton and Hamilton 1974, and GAO 1973). These concerns are by no means unqiue to OR models; they apply to all kinds of modeling efforts, from econometric modeling to simulations of every sort. As Gass (1983) points out, concern over the applicability of models is merely one facet of a larger concern about the applicability of system analytic approaches generally.

These concerns deserve the attention of the modeling community, for they illustrate in stark form the inherent limits of model application. "Pure" approaches to modeling require formal expression and rigor in every aspect of model building. The models that result are so abstract and removed from the realities of fuzzy political problems that they are almost certain to fail as tools for public policy-making. But modeling need not be evaluated under such severe constraints. Models can and do play significant roles in public policy analysis and formulation (Greenberger, Crenson and Crissey 1976, House and McLeod 1977, King 1984, Dutton and Kraemer 1985). These instances of model use demonstrate that modeling has something to offer. Rather than lamenting the difficulties in applying models to the policy process, researchers in modeling and in public policy should focus on improving models as decision aids (Gass 1983), and on improving policymakers' means of using models to advantage in the policy process (Greenberger, Crenson and Crissey; Dutton and Kraemer).

This paper provides an overview of factors shown to be important in two instances of successful implementation and use of policy models in U.S. federal government agencies (King 1983, 1984; Kraemer et al., forthcoming, 1986). The models studied are not classical OR models, but they are clearly of the class

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of decision-aiding models outlined in Gass' 1983 framework for model validation and assessment. The approach to assessment in our study is similar to those suggested by Gass (1977), Kresge (1979) and Wood (1980), but with a slightly different approach to the task. Rather than using ad hoc methods for determining how a model *might* be useful in the policy process, the study attempted to uncover the factors behind the success of two kinds of models that have been widely assimilated and used in federal agencies.

The objective of this paper is to examine the successful implementation and use of models that have become institutionalized as part of the policymaking process. We will discuss the patterns of model use, the relationships between implementation practices and subsequent use, the conditions that affect policymakers' acceptance of model results, and the effects of model use on the policy process. We conclude with a prognosis for policy-oriented modeling in the years ahead.

2. Description of the Research and Methods

The Setting of Model Use

The federal government has supported development of models for policy analysis since the 1960s, with varied results (GAO 1979). Some models have secured strong niches in federal agencies. Some have been used one time and abandoned. Others died in transfer from the developer to the user agency. Many models that have survived to be incorporated into policymaking processes have produced less than ideal results. Frequently, the results of models have clouded and confused the complex policy issues they were supposed to help policymakers deal with. Occasionally, models have proven most useful for applications never intended by their developers. This mixed history of success, together with the fact that modeling can be very expensive, has caused some policymakers and bureaucrats to back away from modeling efforts. It has also discouraged some model builders from applying their talents to the challenge of public policymaking. Given the misgivings of the critics of systems analysis applications to public policy, it is a wonder that there are any successful modeling systems in the public policy arena.

The Nature of Modeling Success

In spite of problems in implementation, a number of highly successful modeling systems are routinely used in federal agencies. These constitute a natural laboratory for investigating what leads to success in model implementation and use. Success of a model refers to a number of outcomes that might occur within the general modeling environment. Definitions about what constitutes success or failure with models have varied from multiattribute attitude measures (Bean et al. 1975) and perceptions of use and utility (Manley 1975, Schultz and Slevin 1975), to intended willingness to adopt an innovation (Souder et al. 1975) and actual innovation implementation over time (Radnor, Rubenstein and Tansik 1970). We adopted the measure of model use as the primary indicator of successful implementation, focusing on two aspects of use: *policy use* and *political use* (Fromm et al., Greenberger et al., Pack and Pack 1977a, b).

Policy use refers to the extent to which a model is used explicitly and seriously to improve the quality or flow of information available to policymakers in the development of policies or programs, in the selection among policies or programs, and in the evaluation of a policy's or program's effectiveness.

Political use refers to the extent to which a model has been used explicitly and seriously for essentially partisan purposes: to delay decisionmaking; to give symbolic attention rather than real attention to an issue; to confuse or obfuscate decisionmaking; to defeat a specific policy by focusing attention on only one side of an argument, although the model could be used to evaluate both sides; to justify or legitimate a decision already made without the model's results; and to add the appearance of technical sophistication to the image or reputation of a policymaker who uses the model or its results.

We also decided to study only those models that have become "institutionalized"; that is, integrated as routine and ongoing components of the policymaking process, and incorporated into the operations of an agency. Our research was aimed at determining how and when four classes of variables affected the success of model use in policymaking. Figure 1 shows the general framework for the study and the relationship between these four classes. The classes of variables affecting model success (outcomes) can be described as follows:

1. *Environmental Preconditions:* availability of financial support for modeling, bureaucratic flexibility or rigidity toward adoption of models and other analytical techniques, and the prevailing bias of the using agency toward reliance on data-based arguments in making proposals and arguing for policies.
2. *Organizational Attributes:* the characteristics of both the model developer and user organizations, including the professional reputation and qualifications of the organizations' technical staffs,

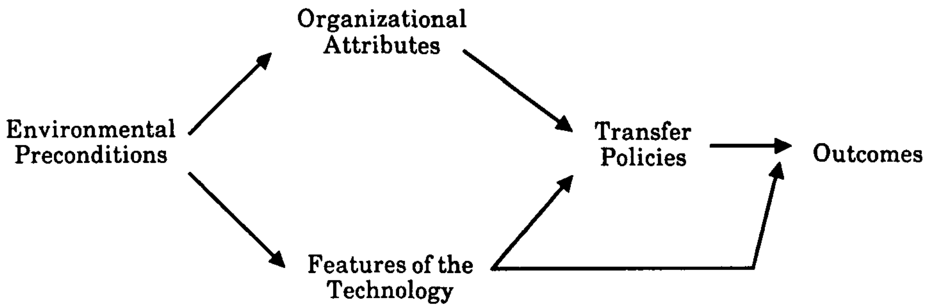

Figure 1. Research framework.

the orientation of the main users toward either policy-making or research, and the extent to which developer organizations involve users in model construction.

3. *Features of the Model Technology:* the sophistication and complexity of the model itself, the data it requires, and the hardware/software infrastructure upon which analysis depends; the relative ease of use of the model package.
4. *Transfer Policies:* the strategies and policies followed by developer and user organizations to move models and their supporting infrastructure from the development laboratory to the using organization, including direct placement of personnel who helped develop the model into the using organization, and the employment of a deliberate marketing and support strategy on the part of the developer organization that incorporates functional division of labor (e.g., sales, maintenance, customer service) to apply specialized expertise to transfer problems.

By studying examples of successful modeling, we were able to determine which of these classes of factors were influential in achieving success, and the mix of circumstances and policies that appeared to work together in accounting for model success.

Data Collection and Analysis Strategy

Our investigation of modeling success involved a literature review, a reanalysis of data collected in a prior study (Fromm et al.), and two intensive case studies. The results reported in this paper are drawn from the case studies, interpreted according to the literature reviewed. The purpose of the case studies was to learn more about the factors that affect model implementation. We selected two models that had established success in implementation in federal agencies, and that had been in use for longer than five years. The first was the Data Resources, Incorporated (DRI 1981) national macroeconometric model system. This system, developed in the late 1960s, was, at the time of the case studies in the early 1980s, the most widely used modeling system in the federal government. The DRI model was exceptionally useful for study because of its proven record of implementation and its wide array of services available to users. The second was a set of two very similar models: the "Transfer Income Model" (TRIM), and its approximate counterpart the "Micro Analysis of Transfer to Households (MATH) model. The TRIM/MATH models are microanalytic simulation models designed to analyze the effects of welfare programs on individuals and households. Both trace their origins to the RIM model developed during President Nixon's Commission on Income Maintenance betweeen 1969 and 1971. TRIM was an extensive refinement and elaboration of RIM developed by the Urban Institute, and was first used in 1973. MATH was built by individuals who had worked on TRIM after they moved to Mathemathica Policy Research, Inc. (MPR). Both models are still in use in several federal agencies. We chose to study both models because the Urban Institute and MPR pursued very different methods of marketing and supporting the models.

Our investigation into the relatively close community of model experts in the fields of macroeconometric and microanalytic simulation modeling led us to other models that provided additional insights. Our study of the DRI model allowed us to observe, although in less detail, the other major macroeconometric models such as the Wharton Economic Forecasting (WEFA) model, the Chase Econometrics model, and the Federal Reserve's MPS model. Similarly, we were able to gather information on two other microanalytic simulation models: the so-called KGB income transfer analysis model used within the Department of Health and Human Services (HHS, formerly Health, Education and Welfare); and the Personal Income Tax Model (PITM) used by the Treasury Department to analyze tax incidence and the dynamics of the tax system. None of these other models were subjected to critical case analysis, and we do not suggest that our comments about them are comprehensive or useful for other than simple comparisons. However, these models did provide important "calibrating" information for our two primary studies.

Our case analyses were conducted through a series of in-depth interviews using the "snowball" sampling technique, in which successive interviewees point to new sources of information. Initial contacts were with the developers and implementation personnel concerned with each of the models, who provided information on the models' development, characteristics, and transfer experiences, as well as lists of the models' users. These users were then interviewed about their perceptions of the models, the nature of their uses, their utility, and the effects of their use on the policymaking process. The model users pointed us to further informants, including policymakers (e.g., agency heads, division leaders, and politicians), and analysts (e.g., statisticians, economists, and policy analysts on congressional staffs and within executive agencies). We further interviewed knowledgeable individuals who were not related to either the model developer organization or the user agencies, but who were familiar with the models, their developers, their users, and the effects of the models on policymaking. They were typically academics and former members of model building or model using groups. The study methodology is elaborated completely in Kraemer et al. These case studies are naturally limited in several respects. They represent only instances of macroeconometric and microanalytic simulation modeling, and certainly do not comprise the complete history of either sort of modeling. They are even less generalizable to the intimate details of other sorts of models, including classical OR models. However, they are very detailed studies of the application of mathematically based, computer-dependent and system-analytic modeling techniques in a complex policymaking domain. As such, they can serve as important analogs of modeling experiences generally. We follow the recommendation of Gass (1983) that those who attempt to improve the record of OR applications in policymaking learn from the experiences and lessons of other fields concerned with building and using complex systems in the fuzzy domain of politics and policy.

3. Findings from the Research

Types of Model Use

Model use in federal agencies is governed by two broad ideologies: a "managerial" ideology and a "political" ideology (King 1984). These ideologies operate under different conditions, and any given model use can be influenced by either ideology, depending on circumstances.

A managerial ideology of modeling presumes that models improve the quality of decisions that emerge from the policymaking process by enhancing the diversity of information available to analysts, managers and policymakers, and by providing the systematic means to reduce uncertainty about the future given certain identifiable assumptions about the present. More sophisticated modeling systems further provide detailed if not altogether reliable answers to "what will happen if . . . ?" questions.

Many federal agency users of macroeconomic and microsimulation techniques adhere to a managerial ideology. For example, they use DRI and other macroeconomic models to make forecasts of future states of the U.S. economy, and these forecasts play an important role in policy formation (McNees 1981, 1982; McNees and Reis 1983). Similarly, agencies concerned with income transfer programs (the Congressional Budget Office, the Office of Management and Budget, the Department of Health and Human Services, and the Department of Agriculture) use MATH or TRIM to make budget projections of future costs for major entitlement programs in the welfare system. Forecasting based on current policy and assumptions about the behavior of key economic forces is probably the most standard application of these models. In most agencies, these forecasts are part of larger information collection processes whereby analysts attempt to reduce the risk of too-heavy reliance on any single information source.

Another important use of modeling capability in policy-making is dynamic simulation of the behavior of policies and programs under different assumptions. By using simulation, policymakers can predict the impacts of alternative policy changes and explore how sensitive particular variables are to alteration. Analysts also use these techniques to fine-tune policy proposals, or to determine the mix of program elements (e.g., eligibility rules) that would produce a desired program objective (e.g., total caseload size or total program cost), by using alternative mixes of various elements to forecast outcomes of these alternatives. These modeling applications contribute to a larger process of policy design by enabling analysts to explore the marginal impacts of alternative policy configurations. All of these more or less technical applications of models—for forecasting, for policy simulation and design, for maximizing available information—operate smoothly under the managerial ideology of modeling. They provide extensive, detailed and quantitative information about the costs and benefits of alternative public policies. Once implemented, they perform this function relatively efficiently.

However, models can also play a major and quite different role under the political ideology of modeling. Policymaking processes produce decisions that affect who wins and who loses as a consequence of governmental actions. The U.S. government is by design a political system whose members compete for power and influence using whatever political weapons they have at their disposal. Information is an especially useful weapon in the policymaking process because it can provide answers to politically relevant questions: Who will be adversely or positively affected by a decision, and in what ways? What policy options do different groups favor or oppose? Information can also be politically useful to the extent that it is consistent with policymakers' biases and can therefore be used in arguments to justify particular positions. The political ideology presumes that models providing politically useful information will invariably be used strategically by members of the policymaking community to achieve political objectives under the political ideology.

A review of model use by federal agencies reveals numerous instances of modeling's interacting with elements of the political and institutional environment to support a political ideology of model use. In the early 1970s, for example, welfare analysts noted a distinct increase in the attention politicians paid to the results of their microsimulation analyses after the data were presented in charts showing the breakdown of income-maintenance program beneficiaries by congressional district. Analysts began to make routine reports of the location of the "winners and losers" of proposed income security program changes in as much geographical detail as possible. In the long run, this treatment of data made the information generally more salient to politicians, and helped to build the constituency of individuals in favor of a methodology that could produce such relevant details.

Our case studies revealed several examples of "counter-modeling," the phenomenon of an agency's acquiring and using a model different from that used by their "opponents." Instead of using MATH to analyze 1976 Food Stamp proposals, the House Agriculture Committee decided to build and use its own simple, ad hoc forecasting model, and thereby avoid internal committee fights over whether MATH had the "liberal" biases the conservatives on the committee said it had. In 1981, when the Administration brought in "supply-side" economics as the theoretical justification for its new tax and budget program, Administration analysts touted a new "supply-side model" (the Claremont model by John Rutledge of the Claremont Graduate School in California) as a counter to the traditional Keynesian econometric models that then dominated the economic modeling scene in Washington.

Another instance of a political use of modeling is "accountability modeling," where an agency implements the same model another agency is using in order to keep that other agency "honest" by monitoring the information available to the rival agency and the credibility of the numbers in the reports the rival agency issues. CBO has cited this approach as one of the rationales for why it adopted MATH and TRIM for its income-security analyses: CBO wanted to use the same models being used at HHS. Similarly, CBO used the KGB model in 1977 to analyze the Administration's welfare reform proposals because it wanted to monitor HHS's estimates using HHS's own technique and thereby reduce forecasting differences introduced by using different methodologies.

Frequency of Model Use

Not all models are used all of the time, even by agencies that have fully implemented them. Some agencies use the DRI model routinely to produce periodic forecasts of the future states of the economy, while others use models only during periods of high interest in an issue. All of the macroeconomic and microanalytic models we studied can be considered successfully implemented, since each has been actually used for managerial or political objectives by at least one agency besides the organization that developed it. However, models that are used frequently give the impression of greater implementation success. The Treasury's PITM model may be the most heavily used of all major microsimulation models, with between 1,000 and 1,500 runs per year for over a decade. Among the models used for broader analytical applications, the macroeconomic models as a class seem more successfully implemented than the TRIM and MATH models, since the former are run more often and are used by a wider number of federal agencies. But frequency of use alone can be a misleading indicator of success because it depends upon a number of independent variables, such as the level and kinds of resources available for modeling, the importance of the particular issue being studied, and the ability of the model to produce information relevant to analyzing or solving a particular problem. Thus, it takes a mixed set of measures to evaluate the nature of model implementation success.

To this end we developed a matrix to characterize contextual factors that affect patterns of agencies' use of computerized planning models (Figure 2). The axes

	Political Interest in the Policy Area		
	Continuous		Episodic
Broad	DRI, Chase and Wharton used by the Troika, CBO, and Treasury	TRIM and MATH used by CBO and HHS	TRIM and MATH used by DOL and USDA
Breadth of acceptance of the model by the community of analysts in the relevant policy area.			DRI, Chase and Wharton used by the GAO
	PITM		
	Fed's MPS		
Narrow		Claremont Model	KGB Model

Figure 2. Patterns of use of selected models across federal agencies in 1981–1982.

represent relationships between characteristics of models and the modeling environment. The horizontal axis denotes the frequency with which the system being simulated in the model is an intensely salient issue in the national policy agenda. At one end are issues of high, continuous saliency, such as the condition of the U.S. economy, or the composition and size of the annual federal budget. At the other end of the continuum are issues that are more episodic in nature, being highly salient only at certain times—such as efforts to enact or revise welfare policies—and less important in the national policy agenda at other times.

The vertical axis of Figure 2 represents another major characteristic of model techniques, the breadth of acceptance for particular models within the community of model users. Some models, such as the DRI, Chase and Wharton macroeconomic models and the PITM, MATH and TRIM microsimulation models, are relatively old and well-established, and have a strong clientele of users. These are the models used most often within their respective policy analysis arenas. In contrast, at the other end of the continuum, are models that are relatively new, undergoing significant change, poorly documented, and used by few agencies. The clientele for these models is small, as is the case for the Claremont model of the U.S. economy or the KGB microsimulation model.

When the models we investigated are plotted on the matrix, the pattern indicates frequency of use of individual models over time and relative to use of other competing models. A cluster of macroeconomic models (i.e., DRI, Chase, Wharton) enjoys routine, continuous use by a large community of agency analysts. The PITM model is heavily used, but only within one agency. Others (e.g., MATH) have strong, broad support among many agencies' analysts, but they are used mainly during erratic episodes of high interest in the policy issue they simulate. Models like the Claremont model have a narrow base of support and enjoy routine use only under extraordinary environmental conditions (i.e., the rise to power of supply-side economists in the Reagan Administration during the budget process for FY 1981). We believe that models that are frequently used and broadly supported are more likely than others to become institutionalized as regular features of the policy analysis process.

Institutionalization of Modeling

While the actual use of a model at least once by an agency is a minimum measure of implementation success, a more comprehensive measure is what we call the institutionalization of models and of modeling per se. Successful model implementation in this broader sense is the result of a complicated coexistence and interaction of "demand pull" by agencies for modeling resources and a strong "supply push" by modelers for transfer of specific models. Over the past two decades, these forces have resulted in the institutionalization of certain models and certain kinds of modeling in U.S. federal agencies. At the same time, significant barriers to model transfer and use continue to exist for many agencies. Modelers who are able to reduce these obstacles seem to experience greater implementation success.

We find that increasingly widespread use of computerized planning models has led to several interesting impacts on the policymaking process that are worth noting.

Demand-Pull for Modeling. Federal agencies' demand for computerized planning models and the quantitative information they generate is high and has been strong for some time. Agencies have bolstered their in-house analytic staffs, increased their use of outside consultants, and expanded their use of sophisticated analytic techniques. Strong demand for all the components of the modeling "package" (models, model experts and input information) to be used either as technical tools or political weapons has led to great investment in the development of policy-relevant models and trained personnel, as well as the transfer and use of models in the policy-analysis process.

Some federal agencies have had more experience and greater success than others in building their analytic capabilities and using them effectively. We found that agencies' opportunities for and interest in implementing policy models result to a large extent from two external political factors: the saliency of the policy area that constitutes an agency's mission, and the nature of competition among actual and potential model users.

The saliency factor affects model implementation in several ways. At any given time, sudden, intense national political interest in an issue tends to increase the resources available to the relevant federal agencies trying to solve these problems. Such interest focuses external attention on how particular policies or programs are doing and on how alternative approaches might improve the situation. For example, sharp increases in the number of Food Stamp participants in 1974 and 1975 led to demands for reform. The Food and Nutrition Service (FNS) came under pressure to estimate what future caseloads and costs were likely to be, and to generate proposals for reform. FNS needed quantitative information for both managerial and political purposes, and it needed this information fast, since focused, intense political interest tends to reduce the time an agency has to investigate a problem and come up with solutions. Political crises demand a response, if only an appearance of action in the form of studying the problem. At such times, agencies often react by channeling resources toward rapid information collection and analysis, and for acquiring expertise (either on the staff or off) to give that information credibility. In the case of FNS, this need meant conducting new ad hoc surveys of the Food Stamp clientele, contracting for the development of a Food Stamp module for the MATH model, and supporting staff and management time necessary to develop rapidly a computing capability and to use MATH for policy analysis and political evidence.

Federal agency responses to hot political issues are also shaped by the nature of political competition among the participants engaged in analysis and policymaking. FNS needed quantitative evidence because program critics (i.e., in the media, in OMB, and on Capitol Hill) had numbers they were using to attack the program, and, since FNS did not have such detailed numbers, it was at a political disadvantage. Acquisition of a number-generating capacity would bring FNS to equal footing, but to maneuver into a position of strength, FNS was eager to find a way to get "better" numbers (e.g., Where did program recipients live? How much money would individual congressional districts lose as a result of changes?). Generating such numbers was a costly and technically problematic proposition, but the political heat enabled FNS to justify the effort.

The FNS modeling efforts are an example of a larger model implementation sequence we observed among competing types of organizations within discrete policy areas. In any given issue area, the first agency to implement a model is usually the one with the primary programmatic responsibility in that area. This organization is drawn by strong managerial and political objectives to acquire data analysis and policy simulation capabilities, and often even provides support for model development or for revising existing research models to meet more applied policy analysis needs. These lead agencies then contract with a dedicated outside modeling agency to provide the service they need (as the FNS did with MATH), or bring the model in-house and use it independently (as HHS did with TRIM). This pattern has emerged in the use of both microsimulation and macroeconomic models.

Agencies that later adopt and use these models do so in part because the lead agency in that policy area has already adopted the modeling capability. These second-stage model implementers often want models predominantly for political objectives. Information—particularly detailed quantitative evidence generated by sophisticated techniques—is a powerful weapon, especially if one participant has it and the other does not. So when one agency has a model, its competitor has a strong political incentive to seek parity by acquiring a modeling capability for itself. Thereafter, model-generated information becomes one of the standard pillars of evidence in policy debates in that area. The political competition at the heart of the policymaking process works together with a strong, generalized demand for "objective" or quantitative evidence to encourage the spread and institutionalization of modeling among agencies of the federal government.

Supply Push for Modeling. Of course, model developers and vendors are not neutral bystanders in this process. Historically, agencies' strong "demand pull" for information and for techniques of analysis has been matched by a powerful "supply push" by modelers for model implementation. The behavior and practices of individual modelers who are oriented towards policy applications—not to mention commerical success—of their models have greatly influenced the spread of modeling generally, and especially the implementation success of those individual models.

Our study revealed that modelers who are more strongly motivated by economic incentives (as opposed to scholarly interests) develop a more aggressive strategy in seeking consumers for their models. They seek out agencies that will not only support model development and acquisition, but also actually implement and use a model over time. These modelers set as their goal the sale of their goods and services to agency users. They adopt policies that encourage transfer, such as an orientation toward servicing clients' needs, designing a comprehensive package of wares, and promoting and pricing the package to obtain customers.

In our study, DRI stands out as an archetype of the successful user-oriented modeler. DRI is a private, commercial firm, established to sell products (i.e., access to its models, forecasts, and data bases) to paying customers. DRI's principals designed its services with the user in mind, combining a wide array of models, data bases, and consulting services into a simple-to-use package, priced to attract a large set of government and corporate users. DRI organized its personnel into specialized teams whose primary responsibility has been to market the package and provide assistance to specific clients. DRI has continuously revised and upgraded its product line and the quality of its services to meet the demands of its important customers. It has allowed for lateral movements of personnel to and from user organizations and academic institutions, and has maintained good relations and contacts across a wide range of organizations, as well as keeping apprised of the changing needs of users. This approach has enabled DRI to adapt its services to the changing political, economic and technological environment in which its customers operate. Key factors in DRI's success in transferring its model to a wide clientele in Washington and in realizing the goal of actual agency use are the commercialization of its modeling enterprise (for which DRI is largely responsible) and DRI's adoption of the previously noted transfer strategies.

Among microsimulation modelers, MPR and its MATH model had achieved the greatest implementation success among a diverse set of agencies. Like DRI, MPR is a private consulting firm offering a user-oriented product package, as well as customized modeling services. MPR's most effective transfer policies have accounted for the need to adjust the process of implementation to the complexity of the technique itself. Because MATH is so complicated and time-consuming to learn to use, MPR has developed important strategies to overcome this barrier, such as a subscription service containing a standard, low-priced model, accompanied by user-oriented documentation, training and consultation. More importantly, MPR has adopted a policy of "personal transfer" which encourages trained personnel to move between modeler and user organizations and among user agencies.

The strong "personalized transfer" policies of the organizations involved in microsimulation modeling have helped spread expertise and thus understanding of and interest in such modeling across a wide range of organizations. However, personalized transfer provides a fragile base of support for modeling in the income-transfer policy areas as compared to the highly institutionalized base that exists among organizations engaged in macroeconomic modeling. This difference is due to the fact that particular microsimulation models are usually focused on narrow policy issues (e.g., income transfer policy) which are the domain of just a few agencies and which tend to be episodic in their political saliency.

Interaction of "Demand Pull" and "Supply Push" for Modeling. Thus, from the 1960s to the 1980s, a number of factors had converged in Washington, D.C., to foster the implementation of computerized planning models among federal agencies. "Supply push" factors associated with modelers' work interacted well with the agencies' "demand pull" for quantitative analyses, facilitating the process of implementing models for use in actual policy analysis. By the mid-1970s, models had become institutionalized, routine fixtures of the policy analysis process. Indeed, the period from the late sixties through the mid-seventies was the golden age of policy analysis, with administrators eager to adopt more systematic management techniques and quantitative tools for program analysis. Politicians wanted to know hard facts about how federal programs were doing and what the impacts of their decisions might be.

Within the welfare policy arena, this situation translated into demands for estimates of the costs of and number of people served by social support programs, as well as evidence on the status of the "war against poverty." The seventies were a period of intense concern over the effectiveness of the nation's large, complex and costly welfare system, and how to reform it. This interest in and controversy over welfare reform combined with a generalized thirst for systematic policy analysis to make microsimulation modeling an attractive tool for social welfare policy analysis in Washington.

In the macroeconomic policy arena, the demand for and supply of analytic techniques also interacted to spread macroeconometric models across the terrain. A number of circumstances enabled modeling capabilities to become available for policy use. Econometric research had developed numerous macroeconomic models. The creation of major economic data bases served as inputs to the models, while advanced computing capability allowed for the construction of more complex models and the ability to process huge time series data files. In the late sixties, a handful of senior economists with an entrepreneurial bent and considerable experience in giving advice to federal policymakers recognized the existence of this growing public market for economic information and analytic services, and established private for-profit firms dedicated to providing services to federal economic analysts. These analysts were eager to gain the ability to make credible economic forecasts and simulations of fiscal and monetary policy options, and thus the "supply push" and "demand pull" factors began to interact in this arena as well.

Barriers to Successful Model Implementation

In spite of the evidence for a gradual move toward increased reliance on modeling, we see several political and technological obstacles to broader implementation of models. We have identified four types of barriers: complexity of the modeling system and its use; problems with the data; perceived inaccuracies of the model; and little relevance of results for policymaking.

The more complex the computerized modeling system is from the user's perspective, the greater the difficulties associated with model transfer and use. Complex systems are harder to learn to use and pose numerous operational problems; thus, many users of models cite model complexity as the largest obstacle in the implementation process.

Curiously, there appears to be a paradox in agencies' attraction to complex models. Many users want models that are technically sophisticated in order to achieve certain managerial objectives (e.g., to simulate the behavior of complex systems, such as the effects of changes in Food Stamp policy on tax and welfare programs) and political purposes (e.g., building credibility of economic forecasts through the use of state-of-the-art analytical techniques). Many agencies seem attracted to particularly complex systems, yet they discover that this very attribute actually prevents them from controlling the technology promptly or efficiently after model acquisition. The MATH model, for example, requires a 2-year investment in personnel training time to become competent to operate the system independently. This high learning cost has often meant that agencies either "use" MATH long before transferring it in-house (through the assistance of MPR's staff who run it at MPR) or attempt to hire MATH analysts away from MPR or other user agencies. In either case, the new user agency cannot gain a sense of control over this complex methodology until either the new employee is socialized into the life of the organization, or existing personnel become sufficiently competent to take over operation of the modeling exercise.

The complexity of computerized microsimulation models such as MATH and TRIM seems to limit the spread of the technology to new users. In contrast, the major econometric models, although complex, often have sophisticated software routines that make their use relatively straightforward. DRI is particularly sophisticated in this regard, and many subscribers to DRI services report that one of its greatest selling points lies in its ease of use.

Problems with the quality and usability of data processed and generated by computerized planning models may be retarding expanded implementation of models. Critics of the MATH/TRIM microsimulation models, for example, have cited data problems such as unrepresentativeness of samples, invalid responses, and old or missing data, as significant drawbacks to policymakers' reliance on the results of model runs (GAO 1976). Microsimulation modelers agree that these problems exist, but they argue that most of them result not from the microsimulation methodology, but from the high costs and reporting difficulties associated with the collection of large, detailed samples of U.S. households—problems that are common to all disaggregated analyses of the behavior of the population affected by complex phenomena. Given the market that exists for analyses of this population, they contend, microsimulation models do the best job they can of processing the huge data sets required to obtain representative samples of the population at risk.

The accuracy and utility of model results have to do with the quality of the data processed, the design of the model itself (i.e., the structural relationships among variables), and the end users' belief in the model's accuracy. Thus, another barrier to successful implementation can be raised when potential users of the information they generate believe the results are biased.

Our research leads us to conclude that any time model results are used in policy disputes or political battles, some partisans are going to be suspicious of the objectivity of the model. However, even in the context of non-politicized policy modeling, model objectivity can be a problem for users.

The issue of perceived model bias is critical for two reasons. First, models' actual predictive accuracies are difficult, if not impossible, to determine because the systems they simulate tend to be dynamic. Forecasts of complex economic and social phenomena can actually change the behavior of the participants in the system modeled, thereby reducing the "accuracy" of the original forecast. In such cases, it is difficult to know whether the error resulted from the modeled system's response to the information provided by the forecast, or from faults in the forecasting model's design, or both. Moreover, although the policymaking community is interested in the accuracy of various computerized planning models, specific organizations rarely care enough to fund thorough assessments of the accuracy of model forecasts. For example, criticisms of the major commercial econometric models abounded after their well-publicized failure to predict the radical changes in energy prices in the early 1970s; yet this resulted in neither a widespread rejection of these models nor a concerted effort to investigate the predictive accuracy of individual models.

Perceived bias in model forecasts hinders model implementation in a second, more political way. Analysts and policymakers who strongly believe that a model reflects a particular economic theory or political perspective will reject or discredit it if they do not share the same views. Our study further indicated that even potential users who wanted to utilize a model that was reputedly biased in line with their own views often decided against using it because they expected their political opponents to discredit any results produced by the model.

A final obstacle to model use has to do with analysts' and policymakers' acceptance of model-generated information as relevant to their own analytic or decision processes. Analysts work with numbers and models on a routine basis, and tend to be strongly supportive of modeling as a key component in their work. However, analysts in the federal policymaking scene are bound by the same practical political realities faced by their politically oriented supervisors: that political survival depends on winning in policy debates. There is no room for ambiguity or the appearance of indecisiveness. Thus, politicians desire point estimates instead of range estimates; answers to "what will..." questions, not "what might..." questions. Lengthy explanations of why a model's estimate is not completely reliable do not make the politician more secure in use of those estimates. An analyst working for a political person typically will not make use of a model unless it can provide concrete assistance in answering the questions of interest to the policymaker. If the model does not do so, the analyst's input will be irrelevant and ignored. Under such conditions, support for modeling in the policymaking organization will break down.

From our case studies, it appears that microsimulation models that are focused on one specific program, such as the PITM model, are the most likely to capture and hold the interest of agency policymakers. These models relate directly to issues that interest agency leaders; use data bases developed and maintained by the agency itself (and in which the agency has confidence); and are often buffered from political warfare because of their narrow, embedded role in the analyses of their home agency. The more generalized policy models are less likely to be met with such immediate trust. MATH and TRIM modelers recognized this issue soon after the models were introduced to federal agencies. To overcome this problem, these modelers began to produce the results of policy simulations in a format that elected officials could more easily grasp. They produced "winners and losers" tables indicating the location and socioeconomic status of groups likely to be affected by different policy changes, so that politicians can learn how their own constituents might be harmed or benefited by policy changes, in addition to hearing about overall programmatic or budget impacts. Yet such politicized use of these models has required modelers to attach qualifiers to their model-generated results and explain their models' inherent limitations to policymakers who want to know a "true" or "exact" answer to some question of political importance. This fact may be unacceptable to policymakers, who do not want their answers "contaminated" by qualifiers or possible estimating errors—even if the questions they ask are vague and the model methodologies are incapable of producing error-free estimates.

Impacts of Modeling on the Policymaking Process

Our study reveals that computerized planning models have a solid footing in Washington, D.C., model-generated "evidence" is now part of the standard vocabulary of policy debates. Models have been institutionalized in agencies throughout the federal government, and analysts strongly believe that at present there are no better tools to help them provide the information policymakers want.

One reason that computerized planning models are here to stay is that most of the actors involved in the modeling-for-policy analysis enterprise have a stake in keeping models on board. Obviously, modelers have commercial, intellectual, and professional interests in designing usable models and selling them to analysts and policymakers. Analysts as a group show a strong commitment to modeling, because it tends to make their jobs more stimulating and enhances their organizational status. Policymakers appreciate the information that models provide, whether it be for decisionmaking purposes or as ammunition for political battles. Although policymakers and analysts are sometimes cynical about the accuracy of models' estimates, they nonetheless support model use because they believe that if they do not use models and argue in numerical terms, their opponents will. In politics, "some numbers beat no numbers every time." In such a system, all of the participants have a stake in keeping modeling going, and no one can afford to take an isolated stand as an objector to the numbers game.

This issue is important because computerized planning models are clearly powerful techniques in terms of technology, economics, and politics. These are sophisticated methodologies capable of processing and analyzing enormous, complex data bases. Models enable their users to produce information that can reduce uncertainty about the future, which in turn gives modelers and analysts personal and organizational power in the form of specialized knowledge. It also gives the organizations that control the models a resource with high political utility that can be used to promote narrow organizational goals.

Computerized planning models also represent a significant amount of political and economic power for those who benefit directly from the sale and use of these costly tools, especially since not all groups in a policy war can afford to acquire or implement them. Individual agencies' estimates of the cost of using one model for one year show the magnitude of the investment: CBO reportedly spent over $1 million on DRI services in 1980; HHS apparently spent $1 million of computer time alone using the KGB model during 1977 (Kraemer et al.). These expenditures are the tip of the iceberg of the costs of computerized modeling, an enterprise strongly supported by agencies of the federal government and showing signs of becoming more institutionalized over time.

Conclusion

Perhaps the real lesson from our study is that the evolution of model use depends on many factors, the most important ones being the presence of the means to do modeling and the desire of bureaucrats and politicians to use model-generated information. Surprisingly, however, our study indicates that the most critical supply factors only enable the adoption of modeling—they do not ensure that modeling will occur. Demand factors provided to be the important variables in explaining whether, how and why modeling was adopted.

Demand for modeling has been a key to model success in the U.S. experience. Even before agencies had computerized planning models to generate forecasts and develop policy simulations, there was a strong demand among U.S. government and private organizations for improving quantitative analysis skills. When DRI assembled its service company to meet the needs of private organizations, it was well-placed for the sudden and explosive growth in demand for modeling by federal agencies. The infrastructure for microsimulation modeling was nonexistent in U.S. federal agencies when the Presidential Commission on Income Maintenance needed a technique to help forecast demand for social services and to simulate the effects on demand of changes in welfare program rules, so an applied modeling effort was mounted to attempt to equip the organization with needed analytical techniques.

Where the means to do modeling were weak but the desire to use models was strong, government agencies invested heavily in the creation of new modeling efforts. If government interest in using models were to wane, either because models failed to show sufficient practical utility or they failed to retain their political potency as weapons, it is doubtful that efforts by modeling suppliers could sustain the modeling market.

We think modeling is here to stay and that the use of models will continue to grow. The demand for models is sustained by the fact that modeling as a science and art is becoming more refined, thus resulting in models that are better able to provide genuine analytical assistance to those in difficult planning situations. As long as models continue to prove their value as useful tools for planning, their political potency as weapons in debate will remain (Kraemer 1985). However, whenever models eventually prove to be no better than guesswork, the demand for models will eventually wane and disappear because their practical and political value cannot be sustained. This observation brings us back to the fundamental fact that modeling technology must provide genuine practical value to its users if it is to survive and persist in use. In the end, the fate of models is not decided by the nature of model providers, or the political needs of model users. Models survive or die based on their ability to help policy analysts and policymakers choose appropriate courses of action from among many complicated alternatives. High pressure sales tactics from modelers, as well as flagrant political uses of models by politicians, can catapult a model to stardom, but unless the model can prove its value on the hard ground of forecasting and simulation, its brightness will be short-lived.

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